



## TRANSLATION

I, Kenji Kobayashi, residing at 2-46-10 Goko-Nishi, Matsudo-shi, Chiba-ken, Japan, state:

that I know well both the Japanese and English languages;

that I translated, from Japanese into English, the specification, claims, abstract and drawings as filed in U.S. Patent Application No.10/025,769 filed December 26, 2001 ; and

that the attached English translation is a true and accurate translation to the best of my knowledge and belief.

Dated: April 16, 2002

  
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- 1 -

## TITLE OF THE INVENTION

IMAGE FORMING APPARATUS AND METHOD OF CONTROLLING THE  
APPARATUS

## BACKGROUND OF THE INVENTION

5           When the print key of an image forming apparatus  
that may be a copying machine is depressed, the  
document set on the document table of the apparatus is  
irradiated with light and light reflected by the  
document is projected into the CCD (charge coupled  
10       device) of the apparatus. Then, an image signal  
(analog signal) showing a voltage level corresponding  
to the density of the projected image formed by the  
reflected light is output from the CCD.

15           The image signal output from the CCD is converted  
into a digital signal by means of an A/D converter to  
make image data, which is then supplied to an image  
processing section of the apparatus.

20           The image processing section appropriately  
processes the image data input to it and outputs the  
processed data. At the same time, it also outputs an  
image clock signal for synchronizing each of the pixels  
of the output image. The image data and the image  
clock signal are fed to a pulse width modulating  
section.

25           The pulse width modulating section performs a  
pulse width modulating operation corresponding to the  
image data. More specifically, a drive signal

synchronized for one or more than one pixel of the image data and having a pulse width (high level period) corresponding to the density of the one or more than one pixel, whichever appropriate, is output from the pulse width modulating circuit. When the drive signal is at level High, the laser unit of the apparatus is energized to emit a laser beam.

The laser beam scans linearly the surface of a photosensitive drum along the axis direction of the drum. The linear scanning operation is repeated successively as the photosensitive drum is rotatedly driven. The direction in which the surface of the photosensitive drum is scanned linearly is referred to as a main scanning direction, whereas the direction in which the linear scanning is shifted as the rotation of the photosensitive drum is referred to as the sub scanning direction.

As the linear scanning operation of the laser beam is repeated, an electrostatic latent image corresponding to the document image is formed on the surface of the photosensitive drum. Then, the electrostatic latent image is developed by means of a development unit to produce a visible image. The produced visible image is transferred to a sheet of copying paper.

An IC circuit is typically used for the pulse width modulating section. The IC circuit shows

input/output characteristics specific to it, which can adversely affect the quality of the image formed by the apparatus.

#### BRIEF SUMMARY OF THE INVENTION

5           Therefore, it is an object of the present invention to provide an image forming apparatus that is not affected by the input/output characteristics of the pulse width modulating section and can always form high quality images.

10           According to the present invention, the above object is achieved by providing an image forming apparatus comprising:

15           a scanning section which reads a document image and outputs image data representing the density of the read image for each pixel;

20           a pulse width modulating section which takes in as input the image data output from the scanning section and performs a pulse with modulating operation of generating and outputting a drive signal synchronized for one or more than one pixel of the image data and having a pulse width corresponding to the density of the one or more than one pixel, whichever appropriate;

25           a laser unit configured to be turned on and off according to the drive signal output from the pulse width modulating section and emit a laser beam during each on period;

          a photosensitive drum;

a scanning section which linearly scans the surface of the photosensitive drum with the laser beam emitted from the laser unit along the axial direction of the photosensitive drum and repeating the linear scanning operation successively in synchronism with the rotation of the photosensitive drum;

a control section which shifts the number of pixels to be used for the pulse width modulating operation of the pulse width modulating section for each linear scanning operation of the scanning section; and

a correcting section which corrects the image data output from the scanning section and input to the pulse width modulating section according to the input/output characteristics of the pulse width modulating section.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitutes a part of the specification, illustrates presently preferred embodiments of the invention, and together with the general description

given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

5       FIG. 1 is a schematic illustration of an embodiment of the invention;

FIG. 2 is a schematic illustration of the photosensitive drum of the embodiment, showing the linear scanning operation of a laser beam;

10       FIG. 3 is a schematic block diagram of a principal part of the control circuit of the embodiment;

FIG. 4 is graph illustrating the input/output characteristics of the pulse width modulating section of the embodiment;

15       FIG. 5 is a schematic illustration of the format of a corrected image data that is registered in a lookup table of the embodiment;

FIG. 6 is a schematic illustration of an image dot pattern that can be formed on the surface of the photosensitive drum of the embodiment;

20       FIG. 7 is a timing chart for the operation of pulse width modulation of a single pixel in an operation of forming the image dot pattern of FIG. 6;

25       FIG. 8 is a timing chart for the operation of pulse width modulation of two pixels in an operation of forming the image dot pattern of FIG. 6;

FIG. 9 is a reference illustration of a defective dot pattern that can be formed on the surface of the

photosensitive drum;

FIG. 10 is a timing chart for the operation of pulse width modulation of a single pixel in an operation of forming the image dot pattern of FIG. 9;

5        FIG. 11 is a timing chart for the operation of pulse width modulation of two pixels in an operation of forming the image dot pattern of FIG. 9;

10       FIG. 12 is a schematic illustration of another image dot pattern that can be formed on the surface of the photosensitive drum of the embodiment;

FIG. 13 is a timing chart for the operation of pulse width modulation of two pixels in an operation of forming the image dot pattern of FIG. 12;

15       FIG. 14 is a timing chart for the operation of pulse width modulation of three pixels in an operation of forming the image dot pattern of FIG. 12;

FIG. 15 is a reference illustration of another defective dot pattern that can be formed on the surface of the photosensitive drum;

20       FIG. 16 is a timing chart for the operation of pulse width modulation of two pixels in an operation of forming the image dot pattern of FIG. 15; and

25       FIG. 17 is a timing chart for the operation of pulse width modulation of three pixels in an operation of forming the image dot pattern of FIG. 15.

#### DETAILED DESCRIPTION OF THE INVENTION

Now, the present invention will be described by

referring to the accompanying drawing that illustrates a preferred embodiment of the invention.

FIG. 1 is a schematic illustration of the embodiment of image forming apparatus that is a digital color copying machine, showing the internal configuration thereof. The image forming apparatus comprises a scanning section 1 for reading a document image and outputting image data representing the density of the read image for each pixel and a 4-serial tandem type printing section 2 for forming a color image on a sheet of copying paper according to the image data output from the scanning section 1.

A document table (glass panel) 3 for setting a document is arranged on the scanning section 1. A document cover 4 is arranged on the document table 3 to cover the latter. It can be opened to access the document table 3.

A carriage 5 is arranged below the document table 3. It is provided with an exposure lamp 6, a reflector 7 and a mirror 8. The carriage 5 is adapted to be moved (reciprocatingly) along the lower surface of the document table 3. The document set on the document table 3 is exposed to light as the carriage 5 is driven to reciprocate along the document table 3 and the exposure lamp 6 is turned on. As a result of the exposure, an image is obtained from the light reflected by the document.



Thus, the carriage 5, the exposure lamp 6, the reflector 7 and the mirror 8 constitute an exposure unit for exposing the document set on the document table 3 to light.

5           The image carried by the light reflected from the document is projected into a CCD (charge coupled device) 14 by means of the mirror 8, mirrors 11, 12 arranged on the carriage 10 and a variable power lens block 13. The CCD 14 comprises a number of  
10           photoelectric converting elements in its light receiving region and is configured to output image signals representing respective voltage levels that correspond to the densities of the red, green and blue images respectively obtained out of the received image  
15           produced by the reflected light. The image signals are fed to a control unit 30.

          The printing section 2 includes image forming sections 10y, 10m, 10c, 10k that are arranged side by side. A conveyor belt 21 for conveying a sheet of  
20           copying paper P, which will be described hereinafter, is arranged under the image forming sections 10y, 10m, 10c, 10k. The conveyor belt 21 extends between a drive roller 91 and a follower roller 92 and driven to move at a constant rate.

25           The image forming sections 10y, 10m, 10c, 10k have respective photosensitive drums 61y, 61m, 61c, 61k. The axes of rotation of these photosensitive drums 61y,

61m, 61c, 61k extend perpendicularly relative to the running direction of the conveyor belt 21.

Charging units 62y, 62m, 62c, 62k, development rollers 64y, 64m, 64c, 64k, toner stirring rollers 67y, 67m, 67c, 67k, toner stirring rollers 68y, 68m, 68c, 68k, transfer units 93y, 93m, 93c, 93k, waste toner collection screws 65y, 65m, 65c, 65k, cleaning blades 66y, 66m, 66c, 66k and discharging units 63y, 63m, 63c, 63k are sequentially arranged around the respective photosensitive drums 61y, 61m, 61c, 61k.

Cassettes 22a, 22b are arranged below the conveyor belt 21. The cassettes 22a, 22b contains respective sheets of copying paper P of different sizes. As the print key of the apparatus is turned on, sheets of copying paper P are taken out one by one from either of the cassettes 22a, 22b. The cassettes 22a, 22b are provided with respective pickup rollers 23a, 23b for taking out sheets of printing paper P.

The sheets of copying paper P taken out from either of the cassettes 22a, 22b are sent to a registering roller 24. The registering roller 24 sends a sheet of copying paper P to the start point of the conveyor belt 21 at timing good for cooperating with the rotating photosensitive drum 61y. An adsorption roller 25 is arranged at the start point in order to provide the sheet of copying paper P with electrostatic adsorptive force.

The sheet of copying paper P sent to the start point of the conveyor belt 21 is then moved to the photosensitive drum 61y. A yellow visible image is formed on the surface of the photosensitive drum 61y immediately before the arrival of the sheet of copying paper P so that the visible image is transferred onto the sheet of copying paper P.

The sheet of copying paper P is then moved from the photosensitive drum 61y to the photosensitive drum 61m. A magenta visible image is formed on the surface of the photosensitive drum 61m immediately before the arrival of the sheet of copying paper P so that the visible image is transferred onto the sheet of copying paper P.

The sheet of copying paper P is then moved from the photosensitive drum 61m to the photosensitive drum 61c. A cyan visible image is formed on the surface of the photosensitive drum 61c immediately before the arrival of the sheet of copying paper P so that the visible image is transferred onto the sheet of copying paper P.

Then, the sheet of copying paper P is moved from the photosensitive drum 61c to the photosensitive drum 61k. A black visible image is formed on the surface of the photosensitive drum 61k immediately before the arrival of the sheet of copying paper P so that the visible image is transferred onto the sheet of copying

paper P.

Thereafter, the sheet of copying paper P is moved from the photosensitive drum 61k to fixing unit 80.

5 The fixing unit 80 fixes the visible images transferred onto the sheet of copying paper P. Then, the sheet of copying paper P is delivered from the fixing unit 80 to the outside of the apparatus main body by a delivery roller 81.

10 On the other hand, a printing engine 50 is arranged above the image forming sections 10y, 10m, 10c, 10k. The printing engine 50 has a laser unit (e.g., a semiconductor laser oscillator) 60 adapted to emit laser beams.

15 The laser unit 60 is operated by the drive signal fed from the control unit 30 and sequentially emits a laser beam B for a yellow image, a laser beam B for a magentan image, a laser beam B for a cyan image and a laser beam B for a black image.

20 The laser beam B for a yellow image emitted from the laser unit 60 is made to irradiate the surface of the photosensitive drum 61y by way of polygon mirror 51, lenses 52, 53 and mirrors 55y, 56y, 57y. The polygon mirror 51 is rotatedly driven by motor 51M. As a result of the rotary motion, the laser beam B swings  
25 in the axial direction of the photosensitive drum 61y. Then, as a result of the swinging motion of the laser beam B, as shown in FIG. 2, the surface of the

photosensitive drum 61y is linearly scanned by the laser beam in the axial direction of the photosensitive drum 61y and the linear scanning operation is repeated successively as the photosensitive drum 61y is  
5 rotatedly driven (linear scanning L1, L2, ... Ln). In this way, an electrostatic latent image corresponding to the yellow image is formed on the surface of the photosensitive drum 61y. The electrostatic latent image is developed by the development roller 64y to  
10 become a visible image.

The direction in which the surface of the photosensitive drum 61y is scanned linearly is referred to as the main scanning direction, whereas the direction in which the linear scanning is shifted as  
15 the rotation of the photosensitive drum 61y is referred to as the sub scanning direction.

The laser beam B for a magentan image emitted from the laser unit 60 is made to irradiate the surface of the photosensitive drum 61m by way of polygon mirror  
20 51, lenses 52, 53 and mirrors 55m, 56m, 57m. As a result of the swinging motion of the laser beam B, the surface of the photosensitive drum 61m is linearly scanned by the laser beam in the axial direction of the photosensitive drum 61m and the linear scanning  
25 operation is repeated successively as the photosensitive drum 61m is rotatedly driven. In this way, an electrostatic latent image corresponding to the

magentan image is formed on the surface of the photosensitive drum 61m. The electrostatic latent image is developed by the development roller 64m to become a visible image.

5           The laser beam B for a cyan image emitted from the laser unit 60 is made to irradiate the surface of the photosensitive drum 61c by way of polygon mirror 51, lenses 52, 53 and mirrors 55c, 56c, 57c. As a result of the swinging motion of the laser beam B, the surface  
10 of the photosensitive drum 61c is linearly scanned by the laser beam in the axial direction of the photosensitive drum 61c and the linear scanning operation is repeated successively as the photosensitive drum 61c is rotatedly driven. In this  
15 way, an electrostatic latent image corresponding to the cyan image is formed on the surface of the photosensitive drum 61c. The electrostatic latent image is developed by the development roller 64c to become a visible image.

20           The laser beam B for a black image emitted from the laser unit 60 is made to irradiate the surface of the photosensitive drum 61k by way of polygon mirror 51, lenses 52, 53 and mirror 55k. As a result of the swinging motion of the laser beam B, the surface of the  
25 photosensitive drum 61k is linearly scanned by the laser beam in the axial direction of the photosensitive drum 61k and the linear scanning operation is repeated

successively as the photosensitive drum 61k is  
rotatedly driven. In this way, an electrostatic latent  
image corresponding to the black image is formed on the  
surface of the photosensitive drum 61k. The  
5 electrostatic latent image is developed by the  
development roller 64k to become a visible image.

The scanning section for scanning the  
photosensitive drums 61y, 61m, 61c, 61k with laser  
beams B is constituted by the polygon mirror 51, the  
10 lenses 52, 53 and the mirrors.

FIG. 3 is a schematic illustration of a principal  
part of the control unit 30.

The image signal output from the CCD 14 is  
converted into a digital signal by A/D converter 31 to  
15 make image data R showing the density of the red image,  
image data G showing the density of the green image and  
image data B showing the density of the blue image B.  
These image data R, G, B are fed to the image  
processing section 32.

20 The image processing section 32 processes the  
image data R, G, B fed from the A/D conversion unit 31  
and outputs image data Y showing the density of the  
yellow image to be produced, image data M showing the  
density of the magentan image to be produced, image  
25 data C showing the density of the cyan image to be  
produced and also image data K showing the density of  
the black image to be produced along with image clock

signals to be used for synchronizing each of the pixels of the output images. The image data Y, M, C, K and the image clock signals are supplied to the pulse width modulating section 34 by way of the correcting section 33.

The pulse width modulating section 34 performs a pulse width modulating operation according to the input image data and referring to the image clock signals. More specifically, it generates and outputs a drive signal synchronized for one or more than one of pixels of the image data and having a pulse width (high level period) corresponding to the density of the one or more than one pixels, whichever appropriate.

Particularly, the pulse width modulating section 34 selectively performs a pulse width modulating operation of generating and outputting a drive signal with a pulse width corresponding to the density of a single pixel in synchronism with each of the pixels of the input image data, a pulse width modulating operation of generating and outputting a drive signal with a pulse width corresponding to the density of two pixels in synchronism with every two of the pixels of the input image data or a pulse width modulating operation of generating and outputting a drive signal with a pulse width corresponding to the density of three or more than three pixels in synchronism with every three or more than three of the pixels of the



input image data according to the instruction from the system controller 35 as the control section.

The system controller 35 controls the overall operation of the image forming apparatus and comprises a control means as described in (1) below as principal functional feature relating to the pulse width modulating section 34.

(1) a control means for selecting two of the pulse width modulating operation for a single pixel, the pulse width modulating operation for two pixels and the pulse width modulating operation for three pixels, in accordance with which one of the image data Y, M, C, K has been output from the image processing section 32 and for causing the pulse width modulating section 34 to carried out the selected two pulse width modulating operations alternately for the operation of linear scanning on the photosensitive drum on a line-by-line bases.

The drive signal output from the pulse width modulating circuit 34 is fed to the laser driver 35. The laser driver 35 turns on the laser unit 60 when the drive signal comes to level HIGH and turns off the laser unit 60 when the drive signal comes to level LOW.

FIG. 4 is graph illustrating the actual input/output characteristics of the pulse width modulating section 34 of the embodiment in comparison with ideal input/output characteristics. More

specifically, when image data "0x80 (hexadecimal value)" is input to the pulse width modulating section 34, if the pulse width modulating section shows ideal input/output characteristics, it is expected to output a drive signal having a pulse width (high level period) exactly 1/2 corresponding to a pixel period T.

However, in reality, it outputs a drive signal with a pulse width (high level period) of  $[T/2 + \Delta T_a]$  because of its actual input/output characteristics. The term "0x" in the expression of "0x80 (hexadecimal value)" shows that it is a hexadecimal number.

The correcting section 33 corrects the image data input to the pulse width modulating section 34 so that the drive signal that is output from the pulse width modulating section 34 in response to the corresponding input of image data to the pulse width modulating section 34 may be same as the imaginary output of a pulse width modulating section 34 showing predetermined ideal input/output characteristics.

More specifically, the correcting section 33 comprises a lookup table as shown in FIG. 5 that stores image data input to the correcting section 33 and the corresponding corrected image data that is supposed to be output from the correcting section 33 and input to the pulse width modulating section 34.

For instance, as image data "0x00" is input to the correcting section 33, corresponding image data "0x00"

that is already corrected is output from the correcting section 33. Similarly, as image data "0x10" is input to the correcting section 33, corresponding image data "0x20" that is already corrected is output from the correcting section 33. Likewise, as image data "0x20" is input to the correcting section 33, corresponding image data "0x30", whichever appropriate, that is already corrected is output from the correcting section 33.

FIG. 6 is a schematic illustration of an image dot pattern that can be formed on the surface of the photosensitive drum 61y as a result of the operation of turning on/off the laser unit 60.

On scanning lines L1, L3, ..., a pulse width modulating operation is conducted for each and every pulse as shown in FIG. 7 so that an image dot having a width corresponding to a pixel period T is formed in synchronism for each pixel.

On the other hand, on scanning lines L2, L4, ..., a pulse width modulating operation is conducted for every two pulses as shown in FIG. 8 so that an image dot having a width corresponding to a pixel period T is formed in synchronism for every two pixels. It will be seen from FIG. 8 that the pulse (high level period) of the drive signal is displaced to the rear end of first the pixel period of the two pixel periods that are used as reference for synchronization, whereas the pulse

(high level period) of the drive signal is displaced to the front end of the second pixel period. An image dot having a width corresponding to a pixel period  $T$  is formed as a result of the combination of the pulse of the first pixel and that of the second pixel.

In this way, a pulse width modulating operation for each and every pixel and a pulse width modulating operation for every two pixels are carried out alternately on a scanning line by scanning line basis to transfer the image dots of the yellow image onto the sheet of copying paper  $P$  in such a way that the image dots are arranged obliquely at a specific angle. Because of the oblique arrangement of image dots at a specific angle, a clear yellow image is formed on the sheet of copying paper  $P$ .

Particularly, as the image data output from the image processing section 32 is corrected by the correcting section 33 and the corrected image data is input to the pulse width modulating section 34, each image dot on the scanning lines  $L1, L3, \dots$  and each image dot on the scanning lines  $L2, L4, \dots$  are made to show a desired width. In other words, a high quality image is formed without being influenced by the input/output characteristics of the pulse width modulating section 34.

The image dot pattern of FIG. 6 is formed by using image dots having a same and identical width. In

reality, the image dot width may vary from image dot to image dot depending on the density of the image read out from the document.

If the correcting section 33 is not provided, an image dot pattern as shown in FIG. 9 may be formed on the surface of the photosensitive drum 61y. Referring to FIG. 9, a pulse width modulating operation for each and every pixel is conducted on scanning lines L1, L3, ... as shown in FIG. 10 and a pulse width modulating operation for every two pixels is conducted on scanning lines L2, L4, ... as shown in FIG. 11.

It will be appreciated from FIGS. 9 through 11 that each image dot on scanning lines L1, L3, ..., shows a width equal to a pixel period T, whereas each image dot on scanning lines L2, L4, ..., shows a width ( $= T + \Delta T_a + \Delta T_b$ ) that is greater than a pixel period T. Thus, it is not possible to make each image dot have a desired width and a defective image dot pattern is produced.

The lines of image dots formed on the surface of the photosensitive drum are made to show an optimal angle that varies from color to color. The angle is appropriately selected as a function of the number of pixels that are processed by the pulse width modulating section 34 for pulse width modulation.

FIG. 12 is a schematic illustration of an image dot pattern in cyan that can be formed on the surface

of the photosensitive drum 61c of the embodiment.

5 A pulse width modulating operation for every two pixels is conducted on scanning lines L1, L3, ... as shown in FIG. 13 so that image dots having a width corresponding twice of a pixel period T are formed in synchronism for every two pixels.

10 A pulse width modulating operation for every three pixels is conducted on scanning lines L2, L4, ... as shown in FIG. 14 so that image dots having a width corresponding twice of a pixel period T are formed in synchronism for every three pixels. It will be appreciated that the pulse (high level period) of the drive signal is displaced to the rear end of first the pixel period of the three pixel periods that are used as reference for synchronization, while the pulse (high level period) of the drive signal corresponds to the entire period of second the pixel period and the pulse (high level period) of the drive signal is displaced to the front end of the third pixel period. An image dot having a width corresponding to twice of a pixel period T is formed as a result of the combination of the pulse of the first pixel, that of the second pixel and that of the third pixel.

25 In this way, a pulse width modulating operation for every two pixels and a pulse width modulating operation for every three pixels are carried out alternately on a scanning line by scanning line basis

to transfer the image dots of the cyan image onto the sheet of copying paper P in such a way that the image dots are arranged obliquely at a specific angle.

Because of the oblique arrangement of image dots at a specific angle, a clear cyan image is formed on the sheet of copying paper P.

Particularly, as the image data output from the image processing section 32 is corrected by the correcting section 33 and the corrected image data is input to the pulse width modulating section 34, each image dot on the scanning lines L1, L3, ... and each image dot on the scanning lines L2, L4, ... are made to show a desired width. In other words, a high quality image is formed without being influenced by the input/output characteristics of the pulse width modulating section 34.

The image dot pattern of FIG. 12 is formed by using image dots having a same and identical width. In reality, the image dot width may vary from image dot to image dot depending on the density of the image read out from the document.

If the correcting section 33 is not provided, an image dot pattern as shown in FIG. 15 may be formed on the surface of the photosensitive drum 61c. Referring to FIG. 15, a pulse width modulating operation for every two pixels is conducted on scanning lines L1, L3, ... as shown in FIG. 16 and a pulse width modulating

operation for every three pixels is conducted on scanning lines L2, L4, ... as shown in FIG. 17.

It will be appreciated from FIGS. 14 through 16 that each image dot on scanning lines L1, L3, ..., shows a width equal to twice of a pixel period T, whereas each image dot on scanning lines L2, L4, ..., shows a width ( $= 2T + \Delta Ta + \Delta Tb$ ) that is greater than twice of a pixel period T. Thus, it is not possible to make each image dot have a desired width and a defective image dot pattern is produced.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiment shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.